Presentation of various more demanding FEM/FVM problems

LincoSim a Virtual Towing Tank Web App for the LINCOLN Project

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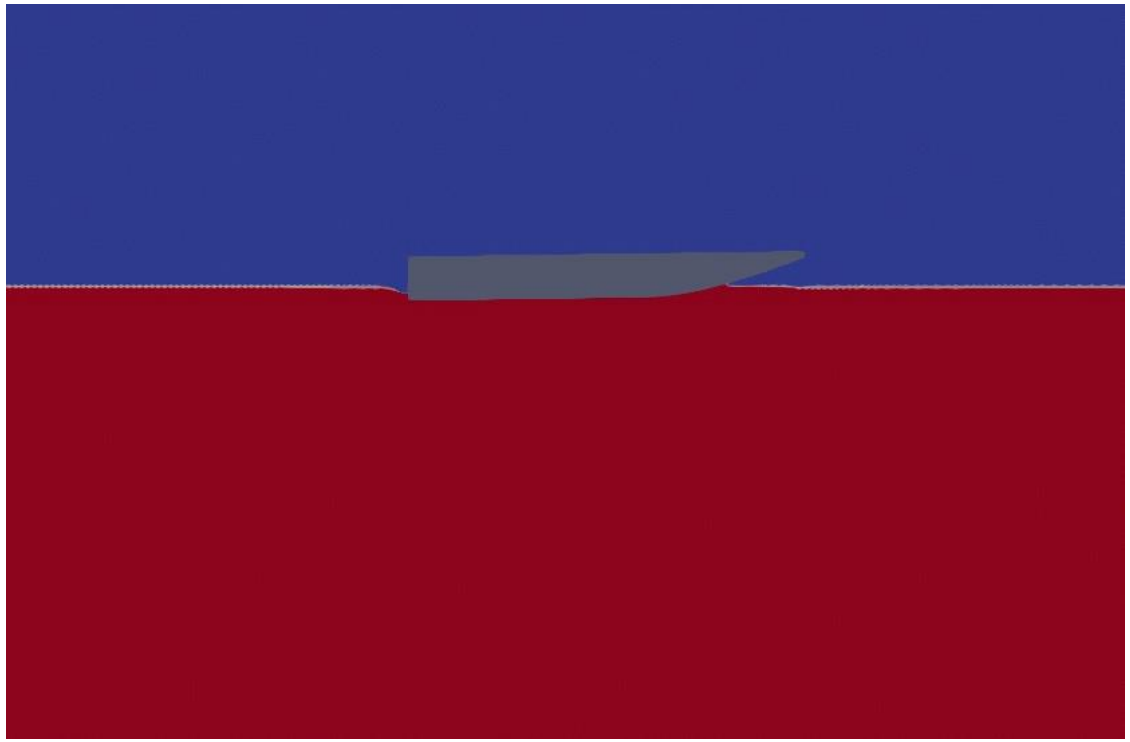
LINCOLN project

- LINCOLN project: http://www.lincolnproject.eu/

Need for a unique virtualized towing tank usable by non expert users for early design analyses

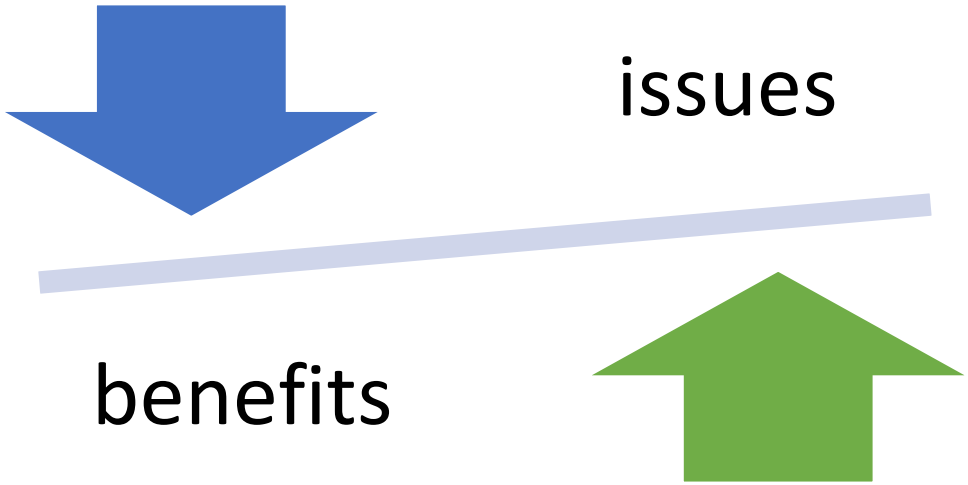
The physical problem:

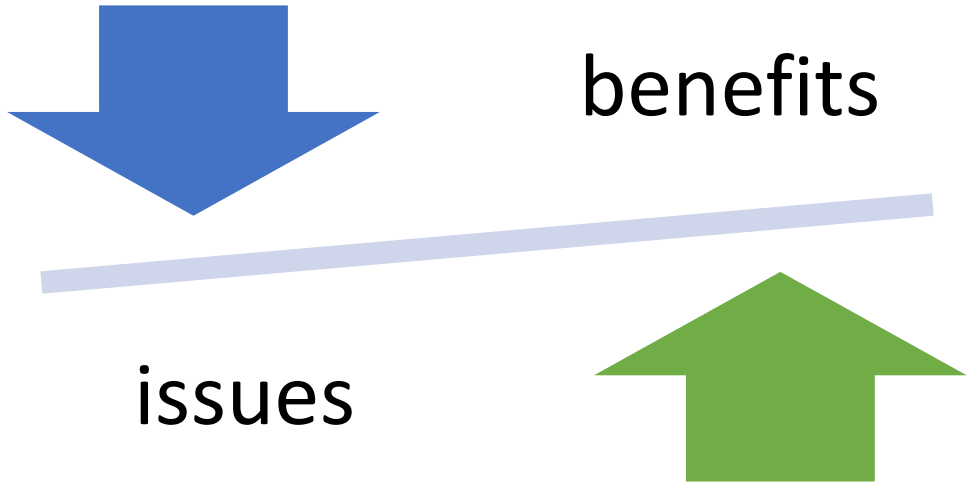
- Hull dynamics equilibrium
- Rigid body dynamics
- Free-surface tracking
- Two immiscible fluids
- Turbulent flow regimen



LincoSim High Level Overview

- CFD is well recognized to be the ideal computational tool to solve the physical problem at hand
- **There are several issues that limits** the effective usability of 3D CFD RANS simulations



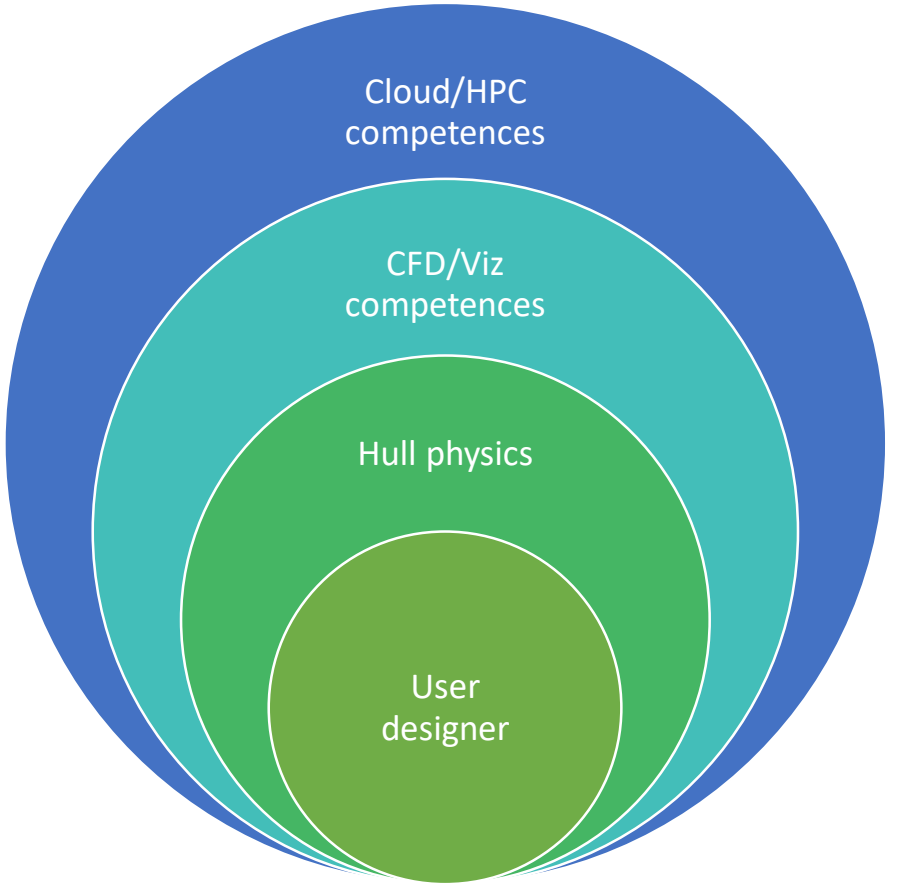


LincoSim High Level Overview

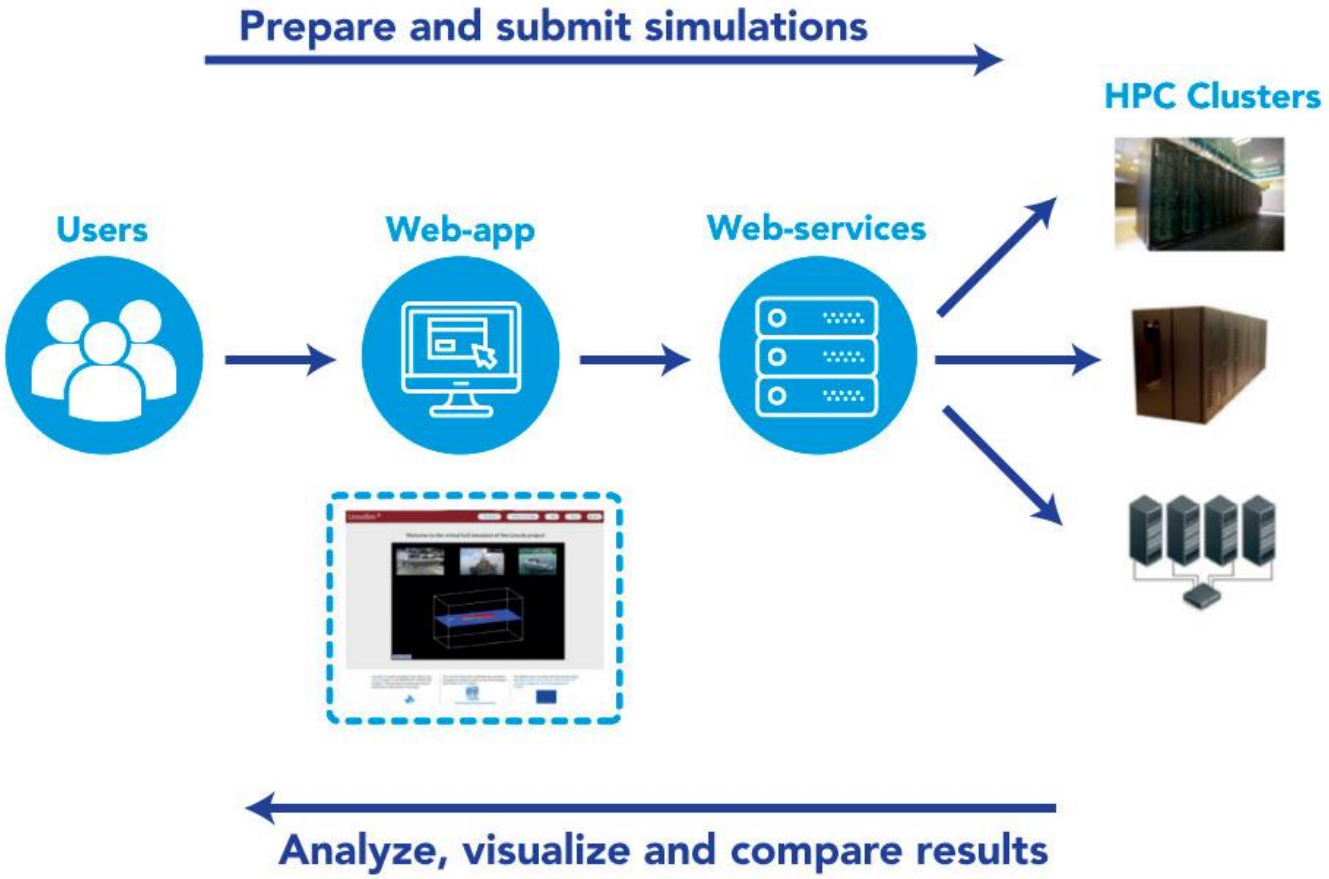
- **Designer standardized way of doing:** instead of solve the full 3D RANS CFD model heuristic/simplified formulas derived from similar hulls and/or from similar towing tank data for systematic hull series are used.
- **CFD is then used only on the final** hull shape design mostly for verification o the design targets (engine power requirements).
- **This approach limits** the effectiveness of the preliminary design screening.

LincoSim background and Rationale

- **Why:** simulate more and in advance to empower design process
- **What:** LincoSim is a web application designed to reproduce the typical/average designer way of doing
- **How:** LincoSim takes advantage of the most advanced web/cloud tools and top class num libs



LincoSim Architecture Sketch



LincoSim High Level Overview

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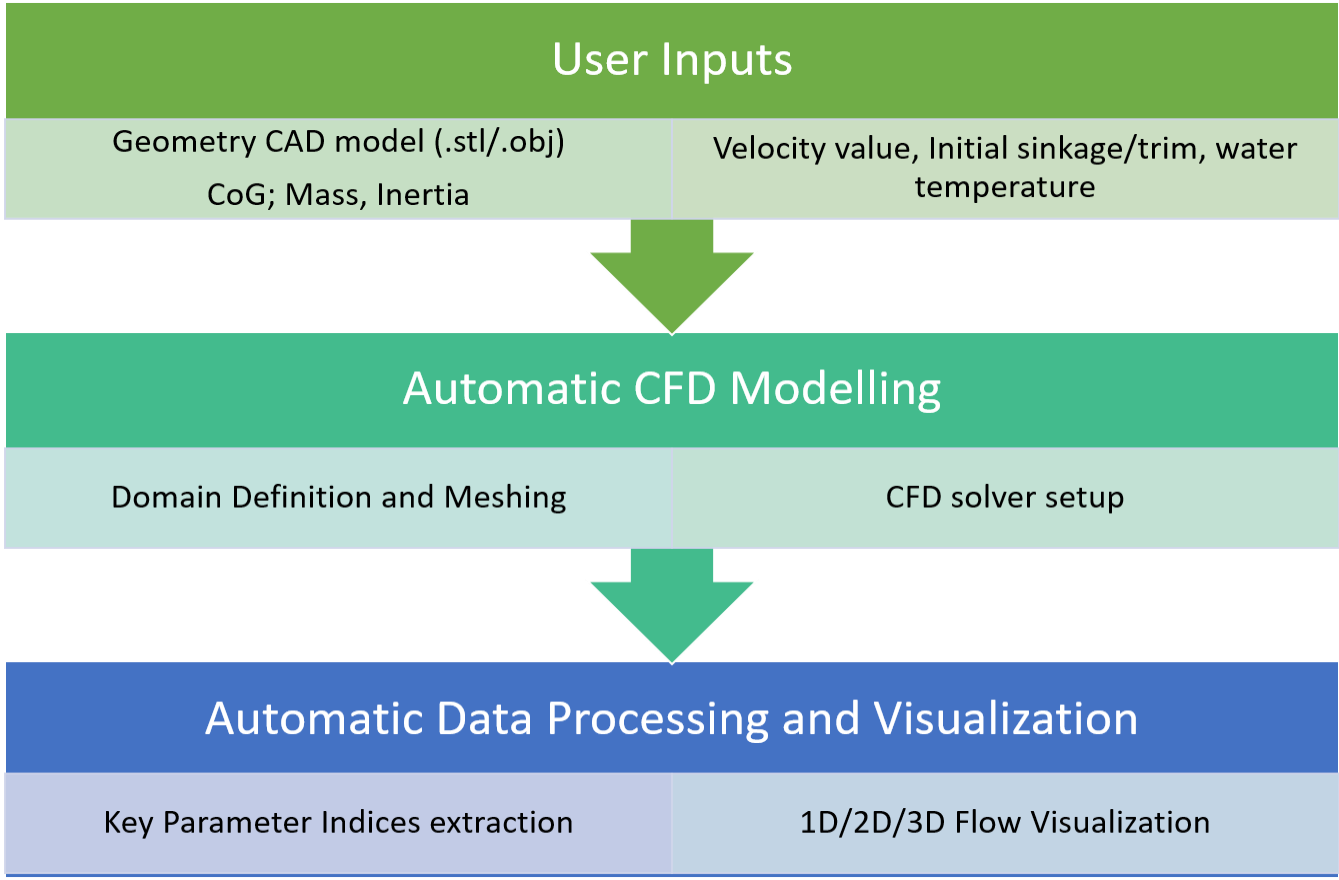
- LincoSim main concepts are standardization and automation
- Simple and intuitive automatic CFD workflow
- Avoid any SW installation



LincoSim data standardization

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INPUTS

Geometry
Triangulated hull

Flow parameters
Hull mass
Hull center of gravity
Hull velocity
Water temperature
Hull inertia
Water z-pos (free-surface)
Hull initial trim-angle

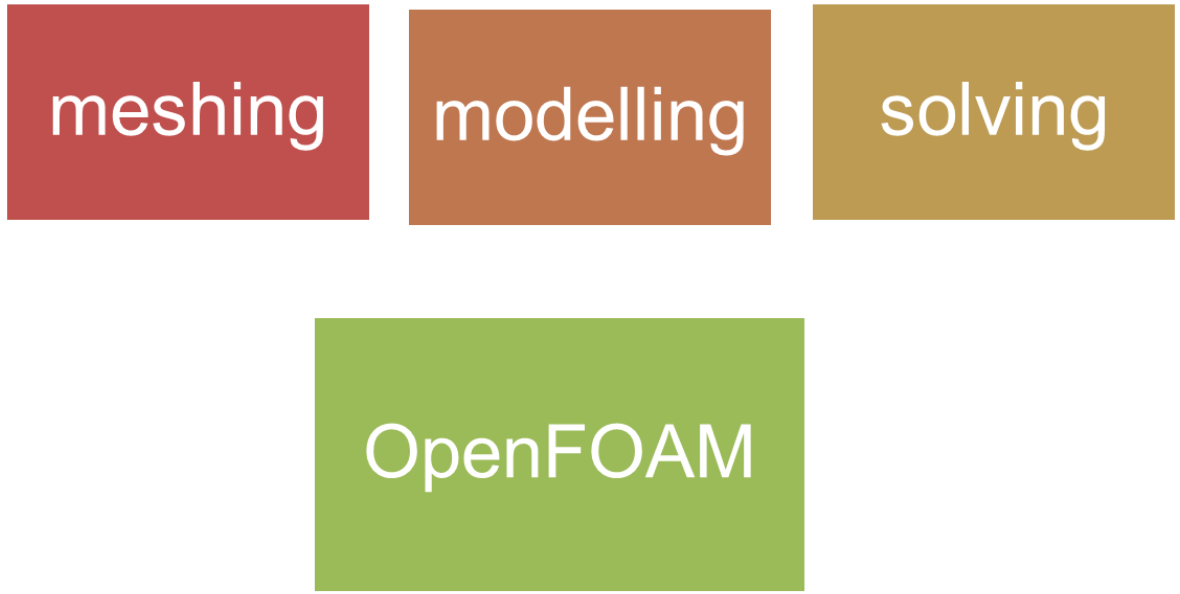
OUTPUTS

Result tables
Drag (pressure and viscous)
Final sinkage
Final trim
Pressure range (min/max)
Maximum wave height on hull
Wet surface area
Displacement

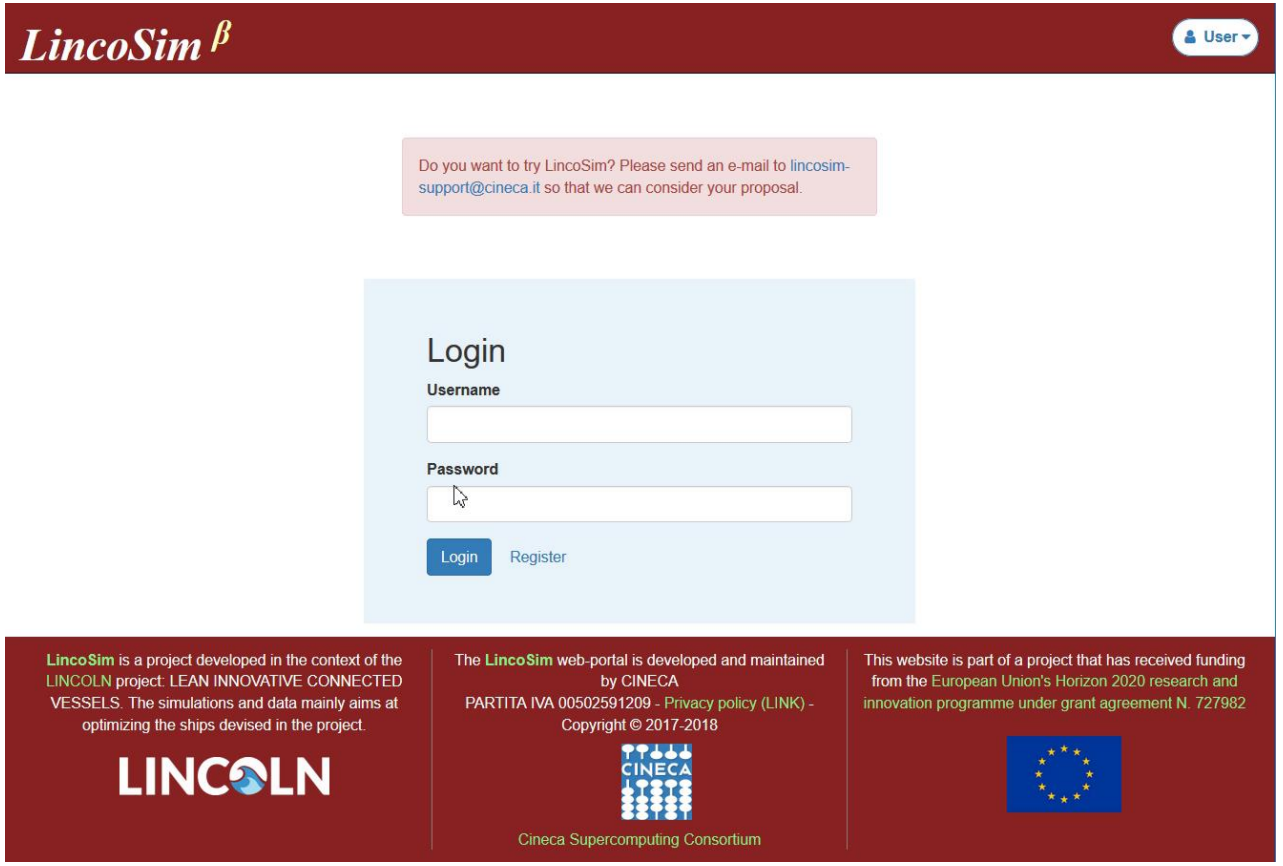
Result visualizations
Time series (forces, body dynamics,…)
2D wave elevation contour
3D wave isosurface
1D elevation plot over lines
Hull pressure plot
Mesh slices
1D pressure slices over lines
3D wet surface on hull
1D profile of wet surface on hull

LincoSim CFD implementation

- **LincoSim** is build on top of a well recognized open-source CFD toolbox: **OpenFOAM**
- **Version: CFD-Direct** distribution v5.0,V7.0 and dev line (https://cfd.direct/openfoam/download/)
- **Visualization and data analysis:** VTK, Pvpython and CSV files



LincoSim


LincoSim β
User
Do you want to try LincoSim? Please send an e-mail to lincosim-support@cineca.it so that we can consider your proposal.
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LincoSim is a project developed in the context of the LINCOLN project: LEAN INNOVATIVE CONNECTED VESSELS. The simulations and data mainly aims at optimizing the ships devised in the project.
LINCOLN
The LincoSim web-portal is developed and maintained by CINECA
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This website is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 727982

LINCOLN Project Usage Stats

- **Usage period**: April 2018 – September 2019
- **Validated hulls against towing tank dedicated measures**: 2
- **CFD data vs EXP data differences**: between 5-10 % for drag and sink, below 15% for pitch values.
- **All relevant differential trends are well caught:** i.e. using LincoSim or towing tank EXP data the same conclusion about hull performances can be drawn.

LINCOLN Project Usage Stats

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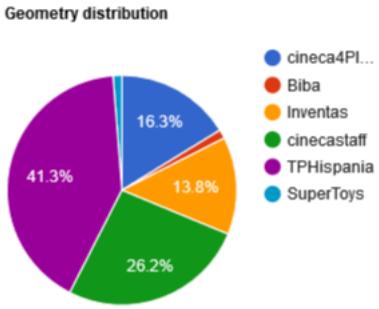
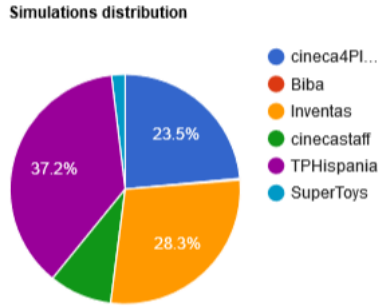
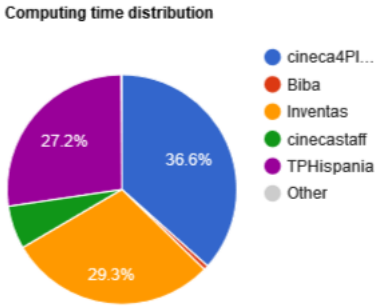
80 geometries



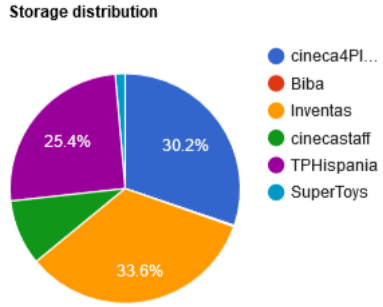
940 simulations

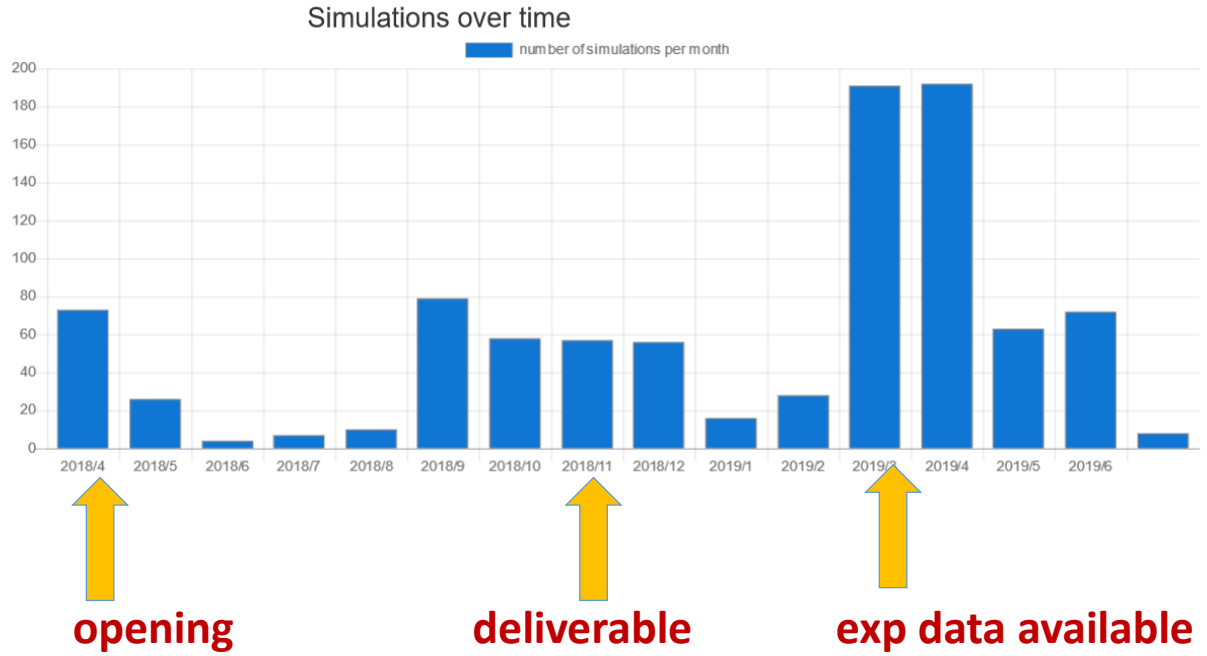


559271.92 computing time



3285887.0 used storage





Selected Example Application

For our example application we selected a planing hull experimentally tested and public:

Authors: Thornhill, E.; Oldford, D.; Bose, N.; Veitch, B.; Liu, P.

Title: Planing hull model tests for CFD validation

(https://nrc-publications.canada.ca/eng/view/accepted/?id=7810bf39-c2de-4bf6-9374-f298ab420b0a)

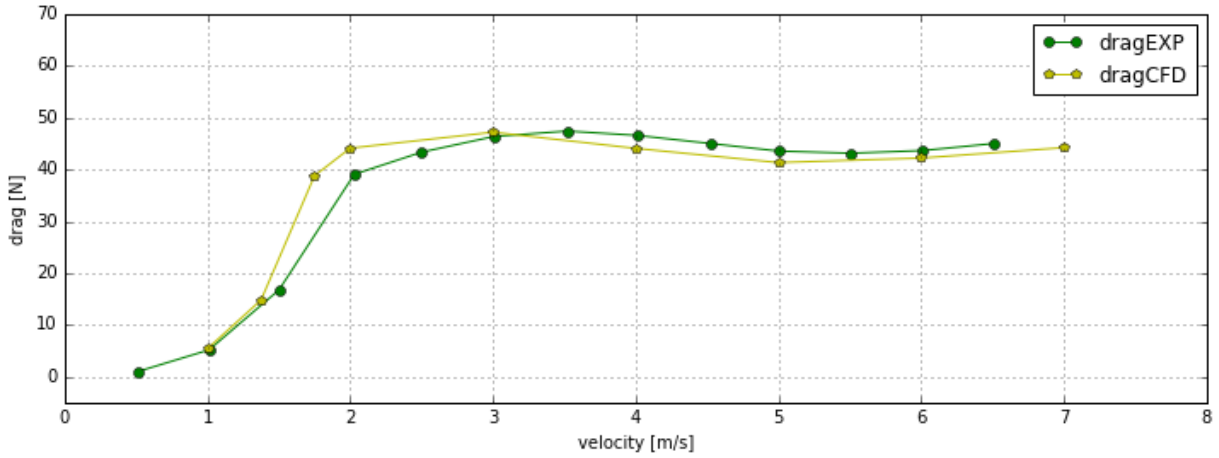
Hull input data table:

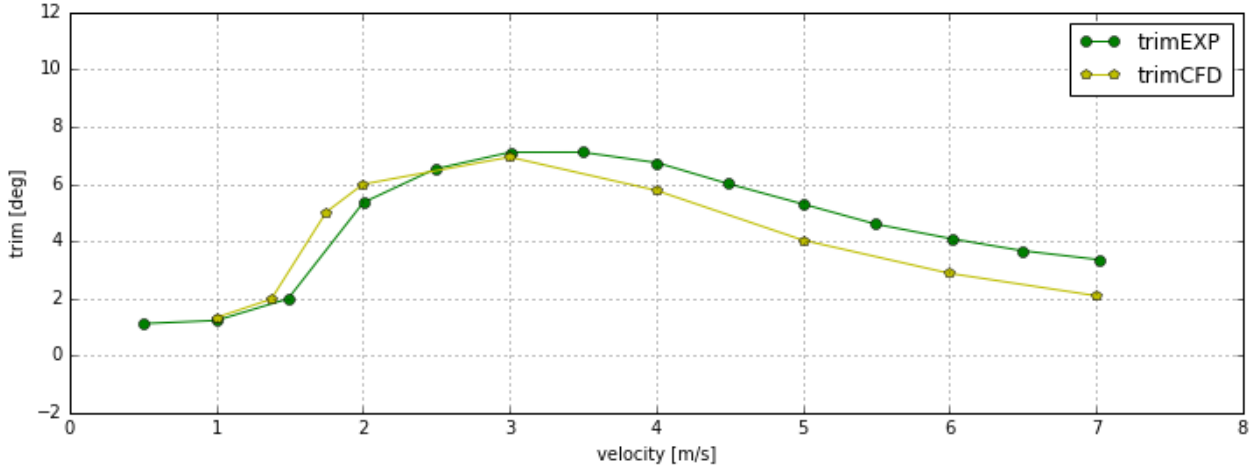
Scale factor	LCG[m]	LOA [m]	Mass [Kg]	U range [m/s]
1:8	0,49	1,475	29,6	1-7

Used EXP data for comparison: velocity/drag curve, velocity/trim curve

Selected Example Application

EXP vs CFD data: in this blind test we had results that are comparable with the ones obtained for the LINCOLN project partner EXP data.





Selected Example Application

- **LincoSim** can be effectively used to submit **hull resistance curve analysis in minutes**
- **Outcomes** can also be analyzed for **decision making**
- **The accuracy** can be considered **acceptable**

Discussion

Support and enhancements to design process:

1. LincoSim shows that **cloud-technologies + open-source numerical libraries + HPC HW** are a suitable way to support modern design activities that rely also on complex physical problems

2. The **final benefits of LincoSim** is to allow a concrete shifting of human time from repetitive/error-prone tasks into meaningful data analysis and decision making activities.

3. Also **the standardization of the undergoing CFD workflow** ensure that all the simulations are performed with similar criteria

Time to result performances:

1. **LincoSim cut down** simulation pre/post processing activities of **about 99%** of the common time thanks to automation ad standardization.
2. **Computational time is reduced** in two ways: using an optimal number of computational cores for the single CFD run and running as many simulations as desired at the time thanks to the selected open-source technology (**license free**)

Discussion

Robustness and users feedback for UI development:

1. during the 18 month of designer users period the service **uptime** was about **99%**.
2. some relevant new feature have been added to the UI.

This is a measure of how **robust the overall web-based implementation** can be even combining a complex set of sw layers and of how easy can be introduce new feature into the UI with the selected web-technology.

Discussion

Users feedback and computational back-end development:

1. Solver calibration made using dedicated towing tank datasets.

2. Solver is today shipped under a single implementation

3. Solver robustness was over **95%** with problems mainly for meshing issues not in solver setup itself.

This is a measure of how robust the overall open-source implementation can be even for a very demanding and complex physical problem.

References

1. Salvadore, F., Ponzini, R. LincoSim: a Web Based HPC-Cloud Platform for Automatic Virtual Towing Tank Analysis. *J Grid Computing* **17,** 771–795 (2019). https://doi.org/10.1007/s10723-019-09494-y

2. Improving the productivity of hull designers with HPC in the cloud: the LincoSim experience; F. Salvadore, R. Ponzini, C. Arlandini - SMC 2019 2019 IEEE International Conference on Systems, Man, and Cybernetics (IEEE SMC 2019).

3. Raffaele Ponzini, Francesco Salvadore, Ermina Begovic, Carlo Bertorello, Automatic CFD analysis of planing hulls by means of a new web-based application: Usage, experimental data comparison and opportunities, Ocean Engineering, Volume 210, 2020,107387, ISSN 0029-8018, https://doi.org/10.1016/j.oceaneng.2020.107387

Thank you for your attention!

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